



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE REACTIONS OF CERTAIN MOIST FOREST MAMMALS TO AIR CONDITIONS AND ITS BEARING ON PROBLEMS OF MAMMALIAN DISTRIBUTION.¹

HOMER E. CHENOWETH.

	PAGE.
I. Introduction.....	183
II. Habitat and Distribution.....	184
III. Experimental Study of the Relation of Environmental Factors to Distribution.....	185
1. Method of Establishing Evaporation Gradients.....	186
2. General Plan of Experiments.....	190
3. Material.....	191
4. Experimental Results.....	191
5. General Discussion.....	197
IV. Summary.....	199
V. Acknowledgments and Bibliography.....	200

I. INTRODUCTION.

The reactions of animals to environmental factors in experiments indicate conditions suitable for them in nature. If such experiments are carried out carefully and at different periods of the life history, the reason for the presence of any animal in a particular environment may be explained in terms of measurable physical factors which it selects and avoids. It has been shown that insects, spiders and amphibians from moist and dry habitats respectively were sensitive to variations of the evaporating powers of the air. The physical factors that determine the rate of evaporation are humidity, pressure, wind and temperature, and these are measured in combination by instruments measuring evaporation. It is the main purpose of this paper to show that representatives of the mammalian group, wood mouse (*Peromyscus leucopsus noveboracensis* Fischer), react to variations in the evaporating power of air in a similar manner regardless of the cause of the variation. The local distribution of an animal is determined by its reactions to environmental factors and its geographic distribution is a function of the distribution of its local habitat, or of conditions indicated by its local habitat. In spite

¹ Contribution from the Zoölogical Laboratory, University of Illinois, No. 82.

of the fact that most theories of distribution are based largely upon mammals we know of no studies of mammalian behavior bearing on this question. However if our knowledge of climate were complete, and if it were possible to bring representatives of all the land animals into the laboratory and test their reactions to physical factors at intervals through their life history a distribution map could probably be made fairly accurate for each species.

II. HABITAT AND DISTRIBUTION.

One of the commonest mammals of any woodland areas of Illinois is the white-footed wood mouse. The habitat of this subspecies is practically coextensive with the woodland. This mouse is sometimes found in the fields when the food supply is short in the forest or it may be tempted to a nearby cornfield. They may migrate to the forest edge or to open cleared places a mile or so from the woods during the summer. They seem to be able to adapt themselves to different moist environments and this is no doubt a great factor in determining their abundance though it seems that houses and barns are seldom if ever entered and it is certain that they never become a household pest. In the woods they are at home under any kind of rubbish and the roots of trees but they are not limited to the ground strata as they are sometimes found living in the trees. The range of the subspecies is from Nova Scotia to central Minnesota, thence south through the humid parts of eastern Nebraska and Kansas and eastward to the Atlantic.

The main purpose of these experiments was to determine the environmental factors that restrict the range of this mouse to the woodland. So many factors make up the environment of any animal and a change in one usually affects the others so that a study of this kind is a very difficult one.

Since the relative humidity is so much greater in the forest than on the prairie (Shimek '11) the writer shows in these experiments that the mouse is sensitive to this difference and reacts to any change in which the humidity is lower than that of the woodland in which its habitat is restricted. Since changes in the relative humidity directly affect the rate of evaporation which in turn affects the physiological processes the conclusion that

the evaporating power of the air is the best index of environmental conditions of the white-footed woodland mouse as well as other land mammals seems evident.

This mouse is primarily a ground stratum animal and since relative humidity decreases from the ground upward one would expect the reactions of such a species to be more pronounced than those from the higher strata, and Shelford ('13) from a series of experiments found (1) animals react to air of a given rate of evaporation whether the rate of evaporation is due to moisture, temperature, or rate of movement; (2) the sign and degree of the reaction to the given rate of evaporation are in accord with the comparative rates of evaporation in the habitats from which the animals were collected though the reaction to evaporation due to temperature was usually sharper; (3) the animals of a given habitat are in general agreement in the matter and sign of the reaction; the minor differences which occur are related to vertical conditions and kind of integument; (4) there is a rough agreement between survival of time in an air of high evaporating power and kind of integument, but no agreement between survival of time and habitat when a number of species of the community are taken together.

Fuller ('11) and McNutt and Fuller ('12) made a comparative study of rates of evaporation in different kinds of forests in northern Illinois. Their figures show that the rate of evaporation was dependent upon the kind of forest and the following results were obtained. Taking 100 as a relative evaporation scale: Cotton wood dunes, 260 per cent.; oak dune, 127 per cent.; oak hickory, 115 per cent.; maple beach forest, 100 per cent. Shimek ('10, '11) made observations on the relative rate of evaporation on the prairies of western Iowa, and his results show that the rate of evaporation is much greater in exposed places than where there is shelter from the sun and wind. The mice apparently avoid higher rates of evaporation by staying in the forest.

III. EXPERIMENTAL STUDY OF THE RELATION OF ENVIRONMENTAL FACTORS OF DISTRIBUTION.

Aron ('11), Rheinhard ('69) and Rubner ('90) have shown that evaporation directly affects the physiological processes of certain

mammals and that if these processes were sufficiently interfered with death of the animal resulted.

1. *Method of Establishing Evaporation Gradients.*

The apparatus for this experiment was designed by Dr. V. E. Shelford and E. O. Deere, and for descriptions and drawings and method of establishing evaporation gradients see BIOL. BULL., No. 25, '13. Descriptions will be made only where changes were made in the apparatus.

The experimental cages for the gradient experiment were designed by Dr. V. E. Shelford. Since a much greater rate of air flow was used in these experiments the cages were made about three times as large as the designer used in his experiments. An extra division of wire mesh was inserted between the fish-tailed burner-shaped introducers and cage apartment. This served to make a more even distribution of the air over the cage. One cage was used for both the experiment and the control. When a control experiment was being made the air was shut off; no moving untreated air was used.

In the beginning, considerable difficulty was encountered in obtaining a constant flow of air through the apparatus and into the cages, due to the fact that the air supply was taken from the university air mains. The pressure in the mains ran about 85 pounds per square inch and as the experiments were conducted at a much lower pressure, from one to five pounds, a reducing valve was placed in the branch line to the apparatus, to reduce the pressure and keep it constant for any particular pressure that was required for the experiment on hand. On account of the well-known acute sensibility of man and mammals to slight differences in air movement it was thought best to pay considerable attention to air movement.

At the outset it was decided to obtain the flow of air in terms of a number of liters per minute as this can easily be determined. This was done by filling a 13-liter bottle with water and finding the time required for the air to displace the water. By proportion the flow in liters per minute was readily obtained but as the operation had to be repeated for each change in the air pressure the work for finding the flow for each different pressure

was tedious and consumed much time, that it was decided to install some device, whereby the flow at any time could be readily obtained.

The subject of air in motion presents one of the most confusing branches of the study of the flow of fluids. The internal eddies, cross currents, and general intricacy of motion of the particles among each other, occurring in a pipe transmitting air, are almost entirely defiant of mathematical expression. It is necessary to adopt as a basis of mathematical investigation the simple assumption that the particles move side by side in such a way that those which at any instant form a lamina or thin sheet, perpendicular to the axis of the pipe or orifice, remain together as a lamina during the further stages of flow. Experiment is then relied upon to make good the discrepancies between the indications of the formula resulting from theory and the actual results of practice.

The laws governing the flow of all fluids are based on the assumption that the density remains constant throughout the flow, as has been stated above. In considering the flow of a gas such as air, however, the laws referred to do not strictly hold. The velocity in an air duct of uniform size varies due to a loss or decrease in pressure which causes an increase in volume and a consequent increase in the velocity. The flow of air, due to a large difference in pressure is most accurately stated by the thermodynamic formula for air discharge under conditions of adiabatic flow. The usual method in stating and measuring small pressures is by noting the height of a column of water which the pressure will maintain in equilibrium or balance in a "U" tube, or manometer.

From this we can analyze the different pressures acting when air flows through a pipe. The flow of air through a pipe or duct is under the influence of three distinct pressures, namely, the velocity, static, and dynamic or total pressures. The velocity head or pressure is defined as that pressure which is required to accelerate the mass from a state of rest to the final velocity attained. The static head or pressure, also termed the frictional or resistance pressure or maintained resistance, is that pressure required to overcome the resistance offered to the flow. This,

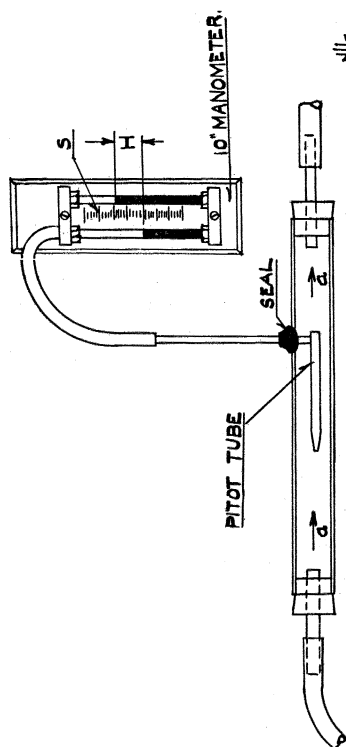
in reality, is the pressure tending to burst the pipe as would be measured by the ordinary pressure gage. The dynamic head or pressure, also termed the total or impact pressure, is the sum of the pressures required to overcome the resistance to flow and create the velocity of discharge. For the many occasions where the measurement of volume, or of volume and pressure, is required, more accurate methods of measurement are often desired than have been commonly used, and the experimenter needs something better than the ordinary anemometer to determine the velocity, or a rubber tube connected to a water gage to measure the pressure. Especially is this so in fan work where the volume varies from zero with the outlet entirely closed, to a maximum, with an unobstructed discharge. The measuring apparatus must be accurate through this wide range.

As has been stated, the usual method employed in stating and measuring small pressures is noted by observing the height of a column of water which the pressure will maintain in equilibrium or balance in a U tube, or manometer. The difference in level of the liquid in the manometer is a measure of the static pressure existing at this point in the pipe or duct. A tube of this description is turned a "Piezometer." In order to obtain correct piezometer readings the most accurate method is to employ a hollow ring connected to the interior of the pipe by six or eight small holes, 0.02 inch in diameter.

Some form of differential or inclined tube gage filled with gasoline and graduated to read in hundredths of an inch of water is usually employed in place of the ordinary U tube, which is not well adapted for reading small pressure differences.

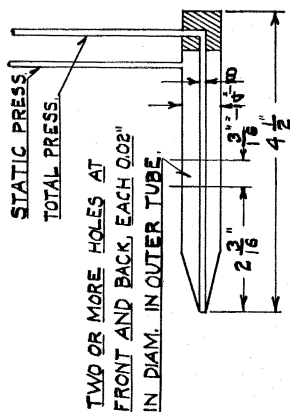
We can now measure the static head or pressure, but as this would not be of much value with air under motion, it is necessary to introduce some device in order that the velocity pressure may be obtained. Such an instrument is known as the "Pitot" tube. This Pitot tube when used with suitable pressure measuring devices, as already described, is particularly well adapted for measuring both the pressure and volume of air flowing through a pipe or duct.

The Pitot tube has the advantage of being small, portable, and can be easily and conveniently placed in small air lines. It is on



ARRANGEMENT OF PITOT TUBE IN AIR LINE.

FIG. 1. For description see text.



STANDARD PITOT TUBE

this account as well as on account of its small size that we describe it here though a better device is described by Hamilton ('17) in the paper which follows. It is a well-known instrument, and consists essentially of two parts, a tube pointing upstream against the flow of air or gas and which converts the sum of the static pressure and velocity pressure into a head which may be measured, and, as a second part, a means of determining the static pressure alone. Although the Pitot tube has long been known and used there is still much doubt in regard to its accuracy and distrust of the results obtained by its use. The form of tube shown in Figs. 1 and 2 has been generally adopted as being the most reliable.

The Pitot tube, as described, was sealed in a glass tube $1\frac{1}{4}$ inches in diameter and 30 inches long, and the connection made from the leads of the Pitot tube to a ten-inch mercury column manometer by means of a piece of one-half-inch rubber tubing. This general arrangement is shown in Fig. 1. After the apparatus had been set up as shown in the sketch the tube leading to the cage was inserted into the neck of the inverted 13-liter bottle and the air turned on. This was done in order that the scale *S* on the mercury manometer could be calibrated in rate of flow of the air. Several such readings were taken for the range of pressures to be used in the experiments, and a scale constructed whereby the rate of flow in liters per minute could be had directly by measuring the height of the mercury in the manometer. The rubber tubing from the exit side of the measuring device was then connected to the leads from the cages containing mice. Some of the later experiments were performed with the equipment described by Hamilton ('17).

2. General Plan of the Experiments.

The mice were put into the experimental cages and air of different evaporating power was secured by passing air of different relative humidities or different temperatures, or at different velocities through the different divisions of the cages. The bottom of the cage was covered with leaves and in order to keep the air from blowing them to one side melted paraffin was poured on them. This was done to procure a rough surface as the mice

would not run over the smooth tin bottom. After the rate of evaporating power was determined the mice were put in the cage, and tracings to the minute and second scale were made for thirty-minute intervals.

A control experiment was made after each experiment so that a comparison could be made in the two cases. An animal might spend as much time in one division of the control cage as it did in the experimental cage but as the graph shows the movements are of a different character. There is no direct orientation in the control cage, and the mice wander back and forth through the different divisions, and seem to be as well satisfied in one division as the other. After one experiment was completed and the mouse had selected the division of the cage which seemed to agree with its physiological make-up, the different gradients were sometimes reversed. The mouse always moved out and sought the conditions it had formerly selected.

3. *Material.*

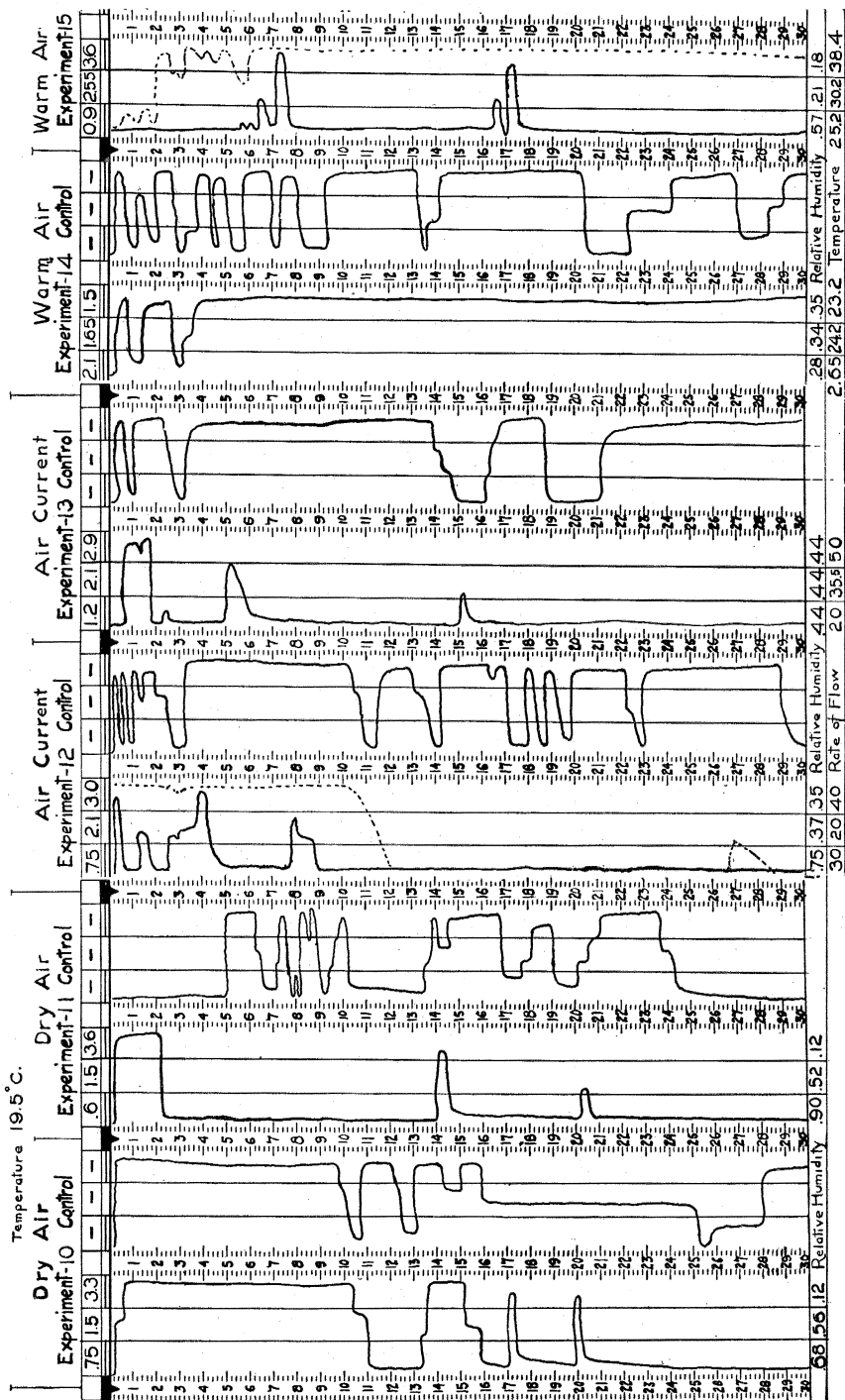
Only one species was used in the following experiments, the white-footed wood mouse, *Peromyscus leucopus noveboracensis*. The experiments were made as soon as possible after the mice were brought into the laboratory, and until experiments were made they were kept under conditions as similar to those of their natural environment as was possible.

4. *Experimental Results.*

(a) *Reaction Experiments.*—The air was passed through sulphuric acid filters.¹ The amount of moisture in the air after treatment depended upon the rate of flow, the temperature, the original humidity of the air and the condition of the filters. These filters became weaker from time to time due to the water removed from the air. Ten-minute exposures were made of the atmometers, as this time was sufficient to calculate readable results. The rates are higher than they were in the experiments of Shelford ('13) as the flows were greater and the same atmometer containers were read. The evaporating results do not represent the rate in the cages for the cases were larger.

¹ BIOL. BULL., No. 25, '13.

Temperature 19.5° C.



68.56.12 Relative Humidity 90.52.12

75.37.35 Relative Humidity 44.44.44

28.34.35 Relative Humidity 57.21.18

2.65242 23.2 Temperature 252302 98.4

CHART I.

The chart shows the reactions of the white-footed wood mouse to air of various evaporative powers. The distance from right to left between the scales represents the length of the cage. The vertical scales are time scales with minutes divided into twelve second periods. The tracings represent the movements of the animals; horizontal distance represents the distance lengthwise of the cage and vertical distance represents time. The solid vertical lines separate the divisions corresponding to the thirds of the cage. The number at the heads of these columns in the experiments represent the evaporation in centimeters for the thirty-minute periods. The relative humidity and temperature data is given at the bottom of the columns. This chart shows a very marked avoidance of the air of high evaporation due to dryness. The lowering of the threshold of stimulation is evident in Experiment 10, as the period spent in the high evaporation conditions is less each time until direct orientation results. The mouse remained in this division of the cage forty-five minutes after the experiment was closed during which time it slept. In Experiment 11 the filters and moisteners were renewed. The avoidance of the air of high evaporation is noted but this mouse reacted much more definitely which was probably due to the dryer air and physiological state of the organism. The only time it left the air of lowest evaporation it was forced out by the experimenter. The figures at the top of the columns represent the evaporation in cubic centimeters during the thirty-minute experimental periods and those at the bottom represent the relative humidity.

The chart shows the negative reaction of a mouse to air of high evaporation due to increased air movement. In Experiment 12 the filters were removed from the air supply and the moisteners were left in. The mouse oriented directly to the air of highest evaporation, and the stimulation seems to be more of a mechanical nature but undoubtedly the direct orientation is a reaction to the higher evaporation due to the rapid air movement as well as the mechanical stimulus and loss of heat. At the close of the experiment the two ends were reversed. The dotted line represents the tracings of the animal's movements. The same avoidance of the air of high evaporation is noted but the mouse did not orient directly. It remained in the unfavorable conditions for ten minutes but became very restless after the second minute and finally moved to the air of the same evaporation it had previously selected. At the end of twenty-seven minutes it was forced out by the experimenter but returned immediately to the air of lowest evaporation. In Experiment 13 the moisteners were removed. When the mouse first encountered the rapidly moving air it was stimulated and kept turning around in the cage and displayed other random movements. After returning to the air of lowest evaporation and the less rapid air movement the turnings were replaced by hesitation at the boundary of the highest evaporation rates and shorter stays in the rapidly moving air.

The chart shows the avoidance of high evaporation due to increase of temperature. In Experiment 14 a difference of 3.2° C. was noted. The standard rate of flow, 27 liters per minute, was used in this experiment. In Experiment 15 the orientation to the higher temperature is more direct, and by comparing the two experiments it is seen that temperature differences are easily detected by these mice. The dotted line represents the tracings of the animal's movements when the ends were reversed at the end of the experiment. The mouse ran around at random for the first five minutes and then selected the air of the same evaporation it had previously selected.

About thirty experiments were performed to test the reactions of these mice to the different evaporating powers of the air. The preceding graphs of a few of the experiments will serve to show the general behavior of these mice in all the experiments.

In Experiment 10, Chart I., the moisteners were becoming very dry and the filters were weak; both were renewed in Experiment 11. The standard rate of flow, 27 liters per minute, was used in both experiments. The mouse was always placed in the division of the cage where evaporation was the lowest. In Experiment 10 the mouse moved directly to the opposite end of the cage where the rate of evaporation was the highest and remained there ten minutes. It behaved quite normally for five minutes, then it grew restless and kept turning around in the corner of the cage; several times it stretched and lay flat and yawned. After moving back to the division of lowest evaporation it made three trips across the cage but the period spent in the dry air was less each time. The threshold of stimulation was lowered each time so that finally the mouse oriented directly, and returned to the air of low evaporation. Throughout the rest of the experiment it remained there and behaved normally. Thirty minutes after the experiment was closed the mouse was still in the same division of the cage. In Experiment 11 the mouse reacted much more definitely, due in part no doubt to the air of higher evaporation and the physiological state of the animal. It remained in the air of lowest evaporation throughout the experiment excepting when it was forced out. A marked negative reaction to the highest evaporation is clear in both experiments.

The rate of flow influences the rate of evaporation in a marked degree. The mice oriented directly in most cases to a very small change in the rate of flow, but I am inclined to attribute this orientation more as a response to a mechanical stimulation; however the higher rate of evaporation was no doubt a factor in determining this response. In their natural environment changes in wind velocity would directly influence their behavior though these variations are very slight in the forest. In their underground burrows it would have little or no effect. The differences in wind velocity existing between the forest and the prairie no doubt play an important rôle in restricting their habitats to the

forest. The rate of evaporation is much greater on the prairie due to a more direct effect of the wind and a higher temperature.

In Experiment 13, Chart I., the rates of flow were 20, 35.5 and 50 liters per minute respectively; the filters and moisteners were both cut out of the air supply leading to the experimental cages. While most of the time was spent in the division representing the lowest evaporation the mouse never behaved normally; the lowest evaporation appearing to be above the optimum, and no doubt it was much greater than that encountered in the natural environment. In Experiment 12, Chart I., the rates of flow were 30, 30, and 40 liters per minute. The filters were cut out in this experiment while the moistener were left in, which accounts for the variation between the two 30-liter flows. The mouse showed a marked avoidance to the more rapid rate of flow. At the end of fourteen minutes the mouse was asleep in the division of lowest evaporation and remained there throughout the experiment. At the end of this experiment the ends were reversed. The mouse up to this time had been asleep but was now stimulated and after the first few minutes grew very restless, turning around in the corner and showing various other stimulation reactions similar to those described under the dry-air experiments. The mouse after ten minutes had elapsed moved to the end of lowest evaporation which it had previously selected and remained there throughout the experiment except at the end of the 27th minute, when it was forced out by the experimenter.

Only a general idea of the effect of raising the temperature can be obtained as the apparatus for this part of the experiments was faulty. It was impossible to keep the temperature constant, and the atmometers and the water in the burettes should have been at the same temperature as the air used, if the results are to be comparable with those obtained at room temperature. Even though the data may not be accurate the number of experiments performed give a fair indication of the general effect upon the organism as is indicated by the general behavior of the mice in all the experiments.

The various temperature gradients were obtained by passing the air through coils of aluminum tubes exposed to steam. In some cases the pressure exerted on the air in these coils was suf-

ficient to raise the temperature 0.5° C. or more and thus produce a gradient. The temperature of the different divisions of the cage was recorded when a constant temperature seems to prevail. Thermometers reading to one tenth of a degree were used.

In Experiment 14, Charts I., the standard rate of flow, 27 liters per minute, was used, and the temperature in the different thirds were 26.5° , 24.2° , and 23.2° respectively. The reactions to the air of highest evaporation was similar to those of the dry and rapidly moving air, and in this experiment the mouse easily detected a difference of 3° C. In Experiment 15 the temperatures were 25.2° , 30.2° , and 38.4° respectively while the rate of flow was approximately 22 liters per minute. The dotted line represents the reaction of the mouse after the ends were reversed at the end of the experiment. The mouse was stimulated at first in the hot air; activity was increased and it moved back and forth in the cage for the first few minutes, after which it selected the same air as before.

(b) *Resistance Experiments.*—The other experiments show that the mice react to conditions of high evaporation. The following were performed in order to determine how long they could withstand these unfavorable conditions. The standard rate of flow used was the same as in previous experiments and the air was dried and moistened as previously described. The mice were put into large-mouthed bottles fitted with inlet and outlet tubes. As soon as the air was turned on the temperature and relative humidity were recorded.

Three experiments were started at the same time. In one bottle the mouse was treated with air of 15 per cent. relative humidity and with an evaporating power of 1.3 c.c. All evaporation readings are given for ten-minute readings. It died after a 41-hour treatment. In the second bottle the mouse was treated with air of 95 per cent. relative humidity and the evaporation was .3 c.c. The experiment was discontinued after 50 hours. The mouse had acted normally throughout the experiment. In the third bottle the mouse was treated with air that was warmed. The humidity was 29 per cent. and the evaporation .7 c.c. Death resulted after a 50-hour treatment. In the warm air and the dry air treatment the behavior of the mice was very similar.

After a few hours' treatment the mouse in the dry air became very active. Beginning at the end of 16 hours it was quiet again for several hours and it then became active again. It would run up and seize the outlet tube with its teeth holding on until shaken loose. In a few minutes it would repeat the performance. After 36 hours it was very weak and was in a comatose condition; it died 5 hours later after 41 hour exposure.

Three mice were treated with air of different rates of flow. The rates in liters per minute were 13, 30.5, and 45, and the rates of evaporation were .35 c.c., .7 c.c., 1.7 c.c. respectively. The mouse in the 45-liter flow died after a 19-hour treatment. Another mouse was put in the same bottle and weighed accurately. It died after a 16-hour treatment and lost 2.69 grams. The mice died with symptoms similar to the salamanders and frogs from dense woods, tested by Shelford ('13) but the time to death was much longer because of the covering of hair; and they are not so restricted to their habitat, as they are sometimes found living up in trees where the rate of evaporation is much greater than on the ground.

5. *General Discussion.*

Whether the evaporation was increased by more rapid rate of flow, by drying the air, or by raising the temperature the general behavior and reactions of the mice were the same. As a rule the mice did not orient as quickly in the dry air as they did to a difference in the rate of flow, or under certain conditions a change in temperature. But differences were far less in the case of mice in temperature gradients than in the case of Shelford's animals; where the evaporation was the same there was no difference. The mouse was always stimulated in the dry air and showed agitation by rapid turnings in the cage, yawning or by stretching and lying flat on the bottom. Sometimes the mouse moved about at random in the division of the cage representing the highest evaporation. This was especially the case when the ends were reversed after the completion of the experiment (Experiments 12 and 15). The selection of the air of lower evaporation was usually accomplished by the mouse moving back and forth along the cage; each period spent in the higher evaporation lowered the threshold of stimulation and finally

avoidance resulted. The problems involved in the results of these experiments are complex and the rate of evaporation plays an important rôle in the distribution of animals.

Why is the habitat of the white-footed mouse coextensive with the woodland area or why is any animal restricted to any particular environment? If any one should attempt to answer these questions he would encounter a very complex physiological problem; however it is evident that this experiment work indicates that the evaporation is the best index of conditions affecting warm-blooded animals.

Change of environmental factors influence organisms in one of three ways (Shelford '14): (a) They may produce death. (b) They may modify structure or behavior. (c) They may stimulate migrating animals and cause them to turn back when an increase or decrease in the factor is noted. These factors have been shown to modify form, color, size and the behavior of animals under experimental conditions, Entemann ('09), (Allen '74) and Sumner ('10).

The integument or covering of an animal has a great deal to do with the power to withstand air of high evaporation. The white-footed mouse with a heavy coat of hair no doubt can withstand these unfavorable conditions more readily than the salamander or other soft-skinned amphibians, since there is no mechanism to prevent loss of water. The shrew (*Blarina brevicauda* Say) has thinner coverings of hair and they live in a much more restricted habitat. It is almost impossible to keep them in the laboratory. The essential factor for their existence seems to be plenty of moisture and they will die if left in the traps over night without water.

When the mice encountered the air of high evaporation there was first a period of stimulation or of heightened sensibility which is indicated by the increasing avoidance of the air of high evaporation after several entrances into it as shown in all the experiments. It is impossible to give a solution which would account for this heightened sensibility, but the work of past investigators gives some interesting data on which to base some conclusions. Waller ('09) showed that a small increase of CO_2 increased the irritability of the nerves. Osborne ('10) showed that CO_2

output increased in dry air. The following table will make this clear.

Date.	Dry Bulb.	Wet Bulb.	Water Loss in Grams.	CO ₂ per Hour.
February 8.....	27.1° C.	15° C.	85 c.c.	21.26
February 13.....	27.1° C.	12.5° C.	94.8 c.c.	23.78

Increased irritability in the mice after a few invasions of the dry air which caused them to turn back more quickly (See Graph 1) was probably due to increased CO₂ production. The differences in water loss and CO₂ given off is no doubt due to the varying humidity and velocity of the air. He showed that the increased water loss means an increased heat loss and therefore increased metabolism if the body of the organism is to remain thermostatic; that the ventilation of the lung is increased when the air temperature is high; that CO₂ varies directly and not inversely as the external temperature. These results show the importance of humidity cannot be overestimated, for temperature data without the known humidity is of no practical value.

It is evident to naturalists that mammals select certain local habitats for their chief places of abode and that their geographic distribution is a function of the distribution of the conditions so selected. In spite of many theories as to the factors controlling distribution of mammals there are apparently no experiments showing the factors to which they react in selecting their habitats. The experiments performed show that the moist forest animals studied avoid air of high evaporating power, due to dryness, rapid movement or high temperature. The negative reactions to air of high temperature which gives the same amount of evaporation as dry air is no sharper than in the case of dry air with no difference in temperature.

The experiments indicate that in the case of the mammals studied the rate of evaporation is more important than temperature in determining their movements. Their resistance to water withdrawal is far greater than that of any other animal in the same community.

IV. SUMMARY.

1. The mice reacted to evaporation whether it was produced by movement, dryness or heat (p. 192, 194-195).

2. The negative reactions to air of high temperature which gives the same amount of evaporation as dry air is no sharper than in the case of dry air with no difference in temperature (p. 192, 196).

3. They behaved normally in air of low evaporation, their optimum, but when the evaporation was increased the mouse was stimulated and reacted negatively (p. 192, 194).

4. Slight differences in air movement were easily detected by the mice (p. 195).

5. The rate of evaporation is the best index of the combined action of wind, temperature, and dryness of the air.

6. The integument of animals is important in determining the rate of evaporation, and animals in the same community show differences in their ability to withstand unfavorable conditions. The hair of the mouse makes it nearly as resistant as the heavily chitinized insects.

7. Evaporation is probably the most important factor in determining the distribution of the white-footed wood mouse.

V. ACKNOWLEDGMENTS AND BIBLIOGRAPHY.

This experimental study has been carried on under the direction of Dr. V. E. Shelford, to whom the writer is indebted for constant advise and criticism. To Dr. Adams I wish to express my appreciation for his suggestions in the study of the life history. To F. M. Miller is due thanks for his valuable assistance in the construction of the apparatus for the measurement of air flow and his suggestions in preparing this manuscript. The equipment was provided by the Graduate School of the University of Illinois.

Aron, H.

- '11 Investigation on the Action of the Tropical Sun on Man and Mammals. *Phil. Jour. Sci., B, Med. Sci.*, Vol. VI., pp. 101-130.

Haldane, J. S.

- '05 Influence of High Air Temperatures. *Jour. Hyg. (Cambridge)*, Vol. V., pp. 494-513.

Hill, Leonard and others.

- '06 Recent Advances in Physiology and Biochemistry. London. Chapters VII. to XXI.

Kennicott, R.

- '56-'58 The Quadrupeds of Illinois, Injurious and Beneficial to the Farmer. *Rep. Comm. Pat., Washington.*

Hamilton, C. C.

- '17 The Reactions of Some Soil Insects to Evaporating Power of Air, Carbon Dioxide and Ammonia. *BIOL. BULL.*, Vol. XXXII., pp. 159-182.

Merriam, C. H.

- '84 The Mammals of the Adirondacks. Pp. 263-271.
- '92 The Geo. Distribution of Life of N. A. with special Reference to Mammalia. Proc. Biol. Soc. Washington, Vol. VII., pp. 1-64.

Shelford, V. E.

- '11 Physiological Animal Georgraphy. Jour. Morph. (Whitman Volume), Vol. XXII., pp. 551-617.
- '12a Ecological Succession, IV. Vegetation and the Control of Land Animal Communities. BIOL. BULL., Vol. XXIII., pp. 59-99.
- '12b Ecological Succession, V. Aspects of Physiological Classification. L. c., pp. 331-370.
- '13 The Reactions of Certain Animals to Gradients of Evaporating Power of Air. A Study in Experimental Ecology. (With a method of Establishing Evaporation Gradients by V. E. Shelford and E. O. Deere.) BIOL. BULL., XXV., pp. 79-120.
- '14 The Significance of Evaporation in Animal Geography. Annals of the Ass. of Am. Geographers, Vol. III., pp. 29-42.

Shelford, V. E. and Allee, W. C.

- '12 An Index of Fish Environments. Science, N. S., Vol. XXXVI., pp. 76-77.
- '13 The Reaction of Fishes to Gradients of Dissolved Atmospheric Gases. Jour. Expt. Zool., Vol. XIII., pp. 207-266.

Shimek, R. B.

- '10, '11 The Prairies. Bull. Lab. Nat. Hist. State Univ. Iowa, April, 1911, pp. 169-240.

Sumner, F. B.

- '08 Some Effects of Differences of Temperature and Humidity upon Post-natal Development of the Mouse. Science, Vol. XXVII., pp. 450-451.

Sutton, H.

- '08 The Influence of High Temperatures on the Human Body, Especially with Regard to Heat-Stroke. Jour. Pathology and Bacteriology, XIII., p. 62.

Walker, A. C.

- '03 Atmospheric Moisture as a Factor in Distribution. S. E. Nat., Vol. VIII., pp. 43-47.

Weese, A. O.

- '17 An Experimental Study of the Reaction of the Horned Lizard, *Pyrosoma modestum* Gir. BIOL. BULL., Vol. XXXII., pp. 98-116.

Wood, F. E.

- '10 A Study of the Mammals of Champaign Co. Bull. Ill. State Lab. of Nat. Hist., Vol. VIII., Art. V., pp. 539-554.